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08/703794

PATENT

## BODY FUNCTION MEASURING APPARATUS

### TECHNICAL FIELD

The present invention relates, in general, to the measurement of body functions with sensors in contact with the skin of a human being and, in particular, to a unit which, in addition to measuring a body function,  
5 provides an indication when the sensor in contact with the skin becomes dislodged from the skin. Although the present invention will be described in connection with skin temperature measurement, it will be apparent that the present invention has broader application.

### BACKGROUND OF THE INVENTION

10 Many probes are in use today to measure or monitor a function of the body with which the probe is in contact or to control or influence a body state or condition. For example, a signal representative of the skin temperature of an infant in an incubator can be used to display the

temperature of the infant and can be used to control the incubator heater to regulate the thermal environment of the incubator. In such an application, it is important that intimate contact between the skin and the probe contact surface which carries the temperature sensor be established and maintained. Should the probe become dislodged, resulting in a total or partial loss of contact, the temperature indication will be incorrect and the control of the incubator heater will be other than what is desired, quite possibly leading to dangerous consequences.

Many loose probe indicators have been suggested or put into actual use. Some are based on using the signals representative of the body function being measured to detect a loose probe condition. Others are based on directly measuring some characteristic of the contact, such as impedance, which changes as the contact changes. Yet others incorporate in the probe special sensors, for example optical sensors, which detect changes in the position of the probe relative to the skin. Generally, the operation and reliability of the prior art loose probe indicators have not been sufficiently satisfactory.

#### SUMMARY OF THE INVENTION

Body function measuring apparatus, constructed in accordance with the present invention, includes a housing and first and second identical sensors spaced apart in the housing and adapted for contact with generally the same area of skin for developing first and second body function signals, respectively. This skin temperature measuring apparatus also includes means responsive to the first body function signal and the second body function signal for developing an indication of the body function at the skin with which the first sensor and the second sensor are in contact and detecting a difference between the rate of change of the first body function signal and the rate of change of the second body function signal which exceeds a predetermined threshold representing a difference in the proximity of the first sensor to the skin and the proximity of the second sensor to the skin.

### BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a bottom view of the sensor portion of body function measuring apparatus constructed in accordance with the present invention.

5 Figure 2 is a functional block diagram of the signal processing portion of body function measuring apparatus constructed in accordance with the present invention.

Figure 3 is a circuit block diagram of the signal processing portion of body function measuring apparatus constructed in accordance with the present invention.

### 10 DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1, body function measuring apparatus, constructed in accordance with the present invention, includes a housing 10 and first and second identical sensors 12 and 14 spaced apart in the housing and adapted for contact with generally the same area of skin for developing  
15 first and second body function signals, respectively. When the body function measuring apparatus of the present invention is adapted for measuring body temperature, first and second identical sensors 12 and 14 are identical thermistors. The first and second signals developed by sensors 12 and 14, respectively, are conducted by wires 15 and 16 to a connector 17 which is  
20 adapted for connection to a unit for displaying a reading of the body function being measured or to control apparatus for controlling the environment of an incubator or both. From this point on, the present invention will be described as applied for skin temperature measurements, although, as indicated above, the present invention has broader application.

25 Preferably, first thermistor 12 and second thermistor 14 are mounted on a flexible substrate 18 which has first and second lands 18a and 18b on which first thermistor 12 and second thermistor 14, respectively, are

mounted. A neck 16c extends between first land 18a and second land 18b and has a width narrower than the width of the first land and the second land.

5 The flexibility of substrate 18 and its configuration, namely the arrangement of neck 18c extending between first land 18a and second land 18b, enhances the freedom of movement away from the skin of one or the other of thermistors 12 and 14 when the particular thermistor is in partial, rather than full, contact with the skin. A condition of partial contact with the skin of either of the thermistors is likely to lead to incorrect temperature indications. By improving the chances of a partially loose thermistor to move  
10 further away from the skin, the relative proximities of the thermistors to the skin will lead to a quicker and more accurate indication of a loose probe condition.

Skin temperature measuring apparatus, constructed in accordance with the present invention, also includes means responsive to the  
15 first temperature signal developed by thermistor 12 and the second temperature signal developed by thermistor 14 for developing an indication of the temperature of the skin with which the first thermistor and the second thermistor are in contact and detecting a difference between the rate of change of the first temperature signal and the rate of change of the second  
20 temperature signal which exceeds a predetermined threshold representing a difference in the proximity of first thermistor 12 to the skin and the proximity of second thermistor 14 to the skin. Referring to Figure 2, which is a functional block diagram of the signal processing portion of skin temperature measuring apparatus constructed in accordance with the present invention,  
25 the first temperature signal  $T_1$  is representative of the temperature of the skin with which the first thermistor 12 and the second thermistor 14 are in contact and is provided as one output.

Second temperature signal  $T_2$  is inverted by an inverter 20. The first temperature signal  $T_1$  and the inverted second temperature signal  
30  $T_2$  are differentiated by differentiating circuits 22 and 24, respectively, to

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develop signals representative of the rate of change of the first temperature signal and the rate of change of the second temperature signal, respectively. The differentiated first temperature signal and the differentiated second temperature signal are combined in a summing circuit 26 to develop, as a  
5 second output, a signal representative of the difference between the rate of change of the first temperature signal and the rate of change of the second temperature signal which, if exceeding a predetermined threshold, represents a difference in the proximity of first thermistor 12 to the skin and the proximity of second thermistor 14 to the skin.

10 Skin temperature measuring apparatus, constructed in accordance with the present invention, preferably also includes means responsive to first temperature signal  $T_1$  and second temperature signal  $T_2$  for detecting a difference between the first temperature signal and the second temperature signal which exceeds a predetermined threshold representing a  
15 failure of one of first thermistor 12 and second thermistor 14. As shown in Figure 2, the inverted second temperature signal  $T_2$  is combined with the first temperature signal  $T_1$  in a summing circuit 28 to develop, as a third output, a signal representative of the difference between first temperature signal  $T_1$  and second temperature signal  $T_2$ .

20 The functions described in connection with Figure 2 can be implemented by either hardware or software, each of which are represented by the circuit block diagram of Figure 3. First temperature signal  $T_1$ , developed by first thermistor 12, is supplied to a temperature indicator/controller 30 which provides a visual indication of the temperature  
25 of the skin with which thermistor 12 is in contact and also serves as a control of the temperature of the space within an incubator hood.

First temperature signal  $T_1$  and second temperature signal  $T_2$ , developed by second thermistor 14, are supplied to a differential circuit 32 which develops a signal representative of the difference, if any, between first  
30 temperature signal  $T_1$  and second temperature signal  $T_2$ . If there is a

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5 difference and this difference exceeds a first predetermined threshold "A",  
for example ten degrees, indicative of a failure of either first thermistor 12 or  
second thermistor 14, an output is developed on a line "Y" and an indication  
of this difference or failure is provided by a failure indicator 34. If there is a  
10 difference between first temperature signal  $T_1$  and second temperature  $T_2$  and  
this difference is less than the first predetermined threshold "A" but greater  
than a second predetermined threshold "B", an output is developed on a line  
"N" and the combination of a level sensing circuit 36 and a differentiating  
circuit 38 develop a signal representative of the difference between the rate of  
15 change of the first temperature signal  $T_1$  and the rate of change of the second  
temperature signal  $T_2$  which, if exceeding a predetermined third threshold  
"C", represents a difference in the proximity of first thermistor 12 to the skin  
and the proximity of second thermistor 14 to the skin, namely a loose probe  
condition. The loose probe condition is indicated by a loose probe indicator  
20 40.

It should be noted that, although a loose probe condition  
produces a difference between in the first temperature signal  $T_1$  and the  
second temperature signal  $T_2$ , determining the difference between the rate of  
change of the first temperature signal  $T_1$  and the rate of change of the second  
25 temperature signal  $T_2$  provides a more reliable indication of a loose probe  
condition. Certain effects, such as thermistors and other sensors wearing  
over time, produce a difference between the first temperature signal  $T_1$  and  
the second temperature signal  $T_2$ , so that a difference between the first  
temperature signal  $T_1$  and the second temperature signal  $T_2$  is not necessarily  
30 due to partial or complete probe dislodgement. Such effects, however, would  
not produce an appreciable, if any, difference between the rate of change of  
the first temperature signal  $T_1$  and the rate of change of the second  
temperature signal  $T_2$ . In contrast, the difference between the first  
temperature signal  $T_1$  and the second temperature signal  $T_2$ , with a threshold  
for this difference set sufficiently high, is useful for identifying a failure of

one of the thermistors which would cause a significant difference between the first temperature signal  $T_1$  and the second temperature signal  $T_2$ .

5 While there have been described preferred embodiments of the present invention, it should be obvious to those skilled in the art that various modifications and changes can be made without departing from the true spirit and scope of the invention.

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